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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : D21F 5/04 | A1

(11) International Publication Number: **WO 98/48107**

(43) International Publication Date: 29 October 1998 (29.10.98)

(21) International Application Number: PCT/FI98/00351

(22) International Filing Date: 21 April 1998 (21.04.98)

(30) Priority Data:
971714 22 April 1997 (22.04.97) FI

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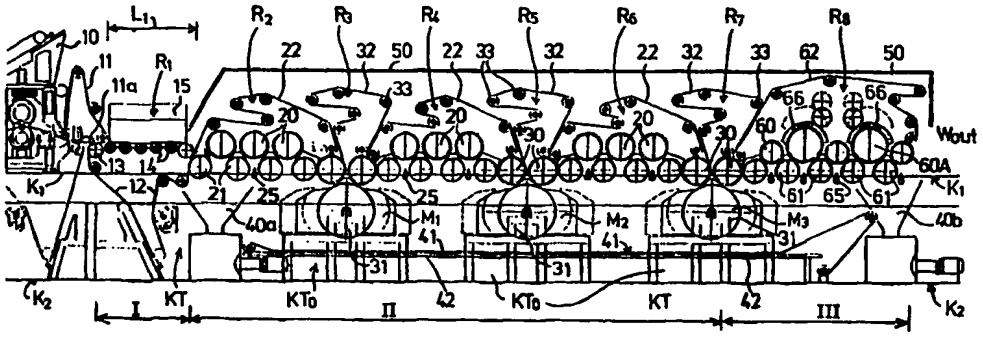
(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
With amended claims.

(54) Title: METHOD FOR OPTIMIZING EVAPORATION DRYING OF PAPER, RUNNABILITY, AND PAPER QUALITY AS WELL AS DRYER SECTION THAT MAKES USE OF THE METHOD IN A PAPER MACHINE



(57) Abstract

A method and an equipment for evaporation drying of the paper web that comes from the press section (10) of a paper machine. The method consists of three successive stages I, II and III that are carried out in the direction of progress of the web (W) as follows: (I) in the first stage, the paper web coming from the press section (10) of the paper machine is heated in a short section (L_1) of the paper machine in the machine direction quickly to a temperature of 55...85 °C, and web breaks of the relatively moist and, thus, weak web (W) are minimized; (II) after the first stage (I), the main evaporation drying of the web (W) is carried out so that the evaporation efficiency (PE) and the rate of increase in the dry solids content (KA) of the web (W) are substantially higher than in the first stage or in the final stage (III), and the web temperature (Tw) does substantially not rise while the drying proceeds (Fig. 4); (III) in the final stage, the drying is continued with a decreasing evaporation efficiency (Fig. 3) and with such an average rate of increase in the dry solids content (KA) of the web (W) in the machine direction as is lower than in the preceding stage (II) but higher than in a conventional cylinder drying with single–wire draw so that the paper quality can be controlled at the same time.

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Method for optimizing of evaporation drying of paper, runnability, and of paper quality as well as dryer section that makes use of the method in a paper machine

The invention concerns a method for evaporation drying of the paper web that comes from the press section of a paper machine from a dry solids content of $k_0 \approx 35...55$ % to a dry solids content of $k_1 \approx 90...98$ %.

Also, the invention concerns a dryer section of a paper machine for carrying out the method.

As is known from the prior art, in multi-cylinder dryers of paper machines, twin-wire draw and/or single-wire draw is/are employed. In twin-wire draw the groups of drying cylinders comprise two wires, which press the web one from above and the other one from below against heated cylinder faces. Between the rows of drying cylinders, which are usually horizontal rows, in twin-wire draw, the web has free and unsupported draws, which are susceptible of fluttering, which may cause web breaks, in particular so in the stages of the drying in which the web is still relatively moist and, therefore, of low strength. This is why, in recent years, ever increasing use has been made of said single-wire draw, in which each group of drying cylinders includes just one drying wire, on whose support the web runs through the whole group so that the drying wire presses the web on the drying cylinders against the heated cylinder faces, whereas on the reversing cylinders or rolls between the drying cylinders the web remains at the side of the outside curve. Thus, in single-wire draw, the drying cylinders are placed outside the wire loop, and the reversing cylinders or rolls inside said loop. From the prior art, dryer sections are known that comprise so-called normal groups with single-wire draw only, in which the drying cylinders are placed in the upper row and the reversing cylinders or rolls are in the lower row.

The highest web speeds in paper machines are to-day up to an order of 25 metres per second and slightly higher, but before long the speed range of 25...40 metres per second will be taken to common use. In such a case, a bottleneck for the runnability of a paper machine will be the dryer section, whose length with the prior-art multi-cylinder dryers would also become intolerably long. If it is imagined that a present-day multi-cylinder dryer were used in a newsprint machine at a web speed of 40 mps, it would include about 70 drying cylinders ($\phi \approx 1800$ mm), and its length in the machine direction would be $\sim$ 180 metres. In such a case, the dryer section would comprise about 15 separate wire groups and a corresponding number of draws over group gaps. It is probable that, in a speed range of 30...40 mps, the runnability of normal prior-art multi-cylinder dryers is no longer even nearly satisfactory, but web breaks would occur abundantly, lowering the efficiency of the paper machine.

In a speed range of 30...40 mps and at higher speeds, the prior-art multi-cylinder dryers would also become uneconomical, because the cost of investment of an excessively long paper machine hall would become unreasonably high. It can be estimated that the cost of a paper machine hall is at present typically about 1 million FIM per metre in the machine direction.

It is known from the prior art to use various impingement-drying/through-drying units for evaporation drying of a paper web, which units have been employed in particular in the drying of tissue paper. With respect to this prior art, reference is made, by way of example, to the following patent literature: *US-A-3,301,746, US-A-3,418,723, US-A-3,447,247, US-A-3,541,697, US-A-3,956,832, US-A-4,033,048, CA-A-2,061,976, DE-A-2,212,209, DE-A-2,364,346, EP-A2-0,427,218, FI-B-57,457 (equivalent to SE-C-7503134-4), FI-B-87,669, and FI-A-931263 (equivalent to EP-0,620,313-A1)*.

One object of the invention is, in connection with increasing of paper machine speeds and with modernizations, to permit fitting of a new dryer section in the place of an existing multi-cylinder dryer. In relation to this, it is a further object of the

invention to provide a dryer section concept that permits ever shorter dryer sections compared with the prior-art dryer sections.

It is a further object of the invention to make it possible to provide a dryer section concept in which different evaporation devices and techniques can be applied optimally in the different stages of drying so that a short construction of the dryer section, a good quality of the paper and a runnability sufficiently free from disturbance are achieved.

The main object of the invention is to provide a novel drying module for a paper web and dryer sections that make use of said module/modules, which are suitable for use at high web speeds of $v > 25$ metres per second, which speeds can be up to an order of $v \approx 30...40$ metres per second or even higher.

It is a further object of the present invention to increase the drying capacity by means of impingement drying and/or through-drying and in this way to make the length of the dryer section shorter, which contributes to an improvement of the runnability of the dryer section.

It is a further object of the invention to provide such a drying method and drying equipment by whose means, in said high speed range, the length of the dryer section in the machine direction can, nevertheless, become reasonable so that its length does not, at least not substantially, exceed the length of the cylinder dryers currently in operation. An achievement of this objective would permit renewals and modernizations of paper machines in existing paper machine halls up to, and even beyond, a web speed of $v \approx 40$ metres per second.

It is a further object of the invention to provide a drying method and a dryer section that applies said method wherein the web is reliably affixed to the drying wire over the entire length of the dryer section so that cross-direction shrinkage of the web can be substantially prevented.

It is a further object of the invention to provide a drying method and a dryer section that applies said method wherein the web is prevented from sticking to the cylinders in the initial end of the dryer section and to improve both the paper quality and the runnability of the paper machine.

With respect to the prior art most closely related to the present invention, reference is made to the applicant's *FI Patent 93,876 (equivalent to US-pat. 5,553,393)* in which a dryer section of a paper machine is described which is composed of cylinder groups with single-wire draw and in which dryer section it is considered novel that, in view of optimizing the drying capacity calculated per unit of length of the dryer section in the machine direction, as the drying makes progress, different ratios k = D/d of the drying-cylinder diameter D to the reversing-roll diameter d are employed, so that, in the first group or groups in the initial end of the dryer section, said ratio $k = k_1$ is higher than the ratio $k = k_2$ in the groups in the middle area of the dryer section, $k_1 > k_2$, and that in the group or groups in the final end of the dryer section, a diameter ratio k_3 is used that is higher than said ratio k_2, $k_3 > k_2$. In said FI patent an effort has been made to choose the diameter ratio D/d of drying cylinder to reversing roll optimally taking into account the different evaporation curves that are carried into effect in different areas of the dryer section. In said FI patent, in the initial end of the dryer section, preferably in one group, said diameter ratio D/d that is used is higher than average, compared with the middle area of the dryer section, for example in the second, third and fourth wire groups. The last mentioned wire groups are in the area where the main evaporation of water takes place from the web. Said higher diameter ratio D/d is also employed in the final end of the dryer section, in which a significant proportion of the evaporation takes place on the curve sectors of the wire and the web on the drying cylinders.

In said FI patent, owing to the optimally chosen and varied diameter ratio k = D/d of drying cylinder to reversing roll, the length of the drying section is estimated to be shortened, at the maximum, by about 10 per cent in comparison with a situation in which said ratio k is used as invariable over the entire length of the dryer section. It has been understood in said FI patent that, as the drying proceeds, the nature of

the drying process will change substantially. However, only the diameter ratio of the drying cylinder to the reversing roll, k = D/d, has been varied in order to optimize the drying, which does, however, not take it far enough from the point of view of optimizing the drying process and the drying configuration, especially since the speeds of paper machines become ever higher and the quality requirements imposed on the paper become ever stricter.

An object of the present invention is further development of the evaporation drying and the dryer sections in paper machines so that the drying process in different parts of the dryer section, in different phases of the drying process, and the dryer section configuration can be optimized and the length of the dryer section shortened or kept unchanged while the speeds become higher.

It is a further object of the invention to optimize the runnability of the paper machine in different phases of the drying procedure so that the efficiency of the paper machine is improved while breaks are fewer. It is a further object of the invention to take advantage of the different structures/methods/processes in the different phases of the paper drying process so that the quality properties of the paper can be optimized.

The nature of the drying procedure has been clarified further in the applicant's recent research and in dryer sections that are in operation and in test runs on a test device. The invention is partly based on the observation that in the dryer section of a paper machine the drying process can be divided into three process stages that are different from each other:

(I) heating stage, in which evaporation does not take place to a substantial extent, but the water present in the web is mainly heated,

(II) main evaporation area, in which the rate of evaporation remains substantially invariable when cylinder drying alone is used and in which the main evaporation of water from between the fibres and from their surface takes place, and

(III) final evaporation area, in which the rate of evaporation becomes lower and the proportion of the evaporation that takes place on the drying cylinders is increased, and in this stage mainly evaporation of water present inside the fibres takes place.

It has also been a problem in the prior-art multi-cylinder dryers that in said first stage (I) it has not been possible to use a temperature high enough in view of optimizing the drying, because, when the paper web is in direct contact with the hot faces of the drying cylinders, at temperatures higher than a certain figure, sticking of the web to the hot surface of the cylinder occurs, from which web breaks and standstills follow. It has been noticed that excessively hot contact drying cylinders also have detrimental effects on the quality properties of the paper.

An object of the present invention is further development of said prior art, elimination of drawbacks of the prior art that were mentioned above and of those that will come out later, and implementation of other objectives of the invention.

In view of achieving the above objectives, the method of the invention is mainly characterized in that the method consists of three successive stages I, II and III that are carried out in the direction of progress of the web in the sequence given as follows:

I in the first stage, the paper web coming from the press section of the paper machine is heated in a short section of the paper machine in the machine direction quickly to a temperature of 55...85°C, preferably to a temperature of about 70°C, and in this section the web is passed so that web breaks of the relatively moist and, thus, weak web are minimized,

II after the first stage I, in this second stage II the main evaporation drying of the web is carried out with such an evaporation efficiency and rate of increase in dry solids content per unit of length of the

dryer section in the machine direction that said evaporation efficiency and rate of increase in dry solids content of the web are substantially higher than in the first stage or in the final stage III, and the web temperature does substantially not rise in the second stage while the drying proceeds,

III in the third and final stage, the drying is continued with a decreasing evaporation efficiency and with such an average rate of increase in the dry solids content of the web in the machine direction as is lower than in the preceding stage II but higher than in a conventional cylinder drying with single-wire draw so that the paper quality can be controlled at the same time.

On the other hand, the dryer section in accordance with the invention is mainly characterized in that, after the press section of the paper machine, the dryer section comprises the following dryer units that are placed in the given sequence in the machine direction:

in order to carry out the first stage I of the method, the first unit is a drying wire unit in which the paper web runs past blow boxes and/or radiation dryer units, by whose means the web is heated without a direct contact with heated faces,

in order to carry out the second stage II of the method, dryer units that comprise at least one single-wire group with single-wire draw that is open towards the bottom, in which the contact drying cylinders are in the upper row and the reversing suction cylinders are in the lower row so that removal of broke can take place downwards by the effect of gravity.

In the first stage I in the method in accordance with the invention, such a construction of the dryer section is used as also has optimal runnability properties so that in this stage, when the web is still moist and relatively weak, web breaks can be minimized. The final stage III of the method of the invention is carried out with such

solutions of equipment as also permit control of quality properties of paper, such as brightness, curl, etc.

With the method in accordance with the present invention and with a dryer section concept that carries out the method it is possible to achieve the objectives mentioned above and to eliminate said drawbacks substantially. In accordance with the invention it is possible to provide a dryer section that is shorter and more compact than in the prior art also at high machine speeds so that the operating quality of the dryer section still remains good.

In the method and the dryer section in accordance with the invention the web is preferably dried sot that in the first stage I the drying energy is at least mainly applied from the side of and through the upper surface of the web, in the second stage II the drying energy is applied to the web from the side of and through its lower surface, and in the third stage III the drying energy is applied to the web from and through its both surfaces.

In the following, the invention will be described in detail with reference to some exemplifying embodiments of the invention illustrated in the figures in the accompanying drawings, the invention being by no means strictly confined to the details of said embodiments.

Figure 1A is a schematic side view of a dryer section in accordance with the invention in which the method in accordance with the invention can be applied favourably.

Figure 1B shows a preferred contact-drying/impingement-drying unit used in a dryer section in accordance with the invention, of which units there are three in the dryer section shown in Fig. 1, separated from one another by single-wire groups.

Figure 1 C shows the last wire group of the dryer section in a scale larger than Fig. 1A, in which group the stage III of the method in accordance with the invention is carried out.

Figure 2 is a graphic illustration of the different stages of the method in accordance with the invention in a system of coordinates of dry solids content of the web - length of the dryer section in the machine direction, compared with a prior-art multi cylinder dryer.

Figure 3 is a graphic illustration similar to Fig.2 of the drying method in accordance with the invention and of a prior-art drying method in a system of coordinates of evaporation capacity - length of the dryer section in the machine direction.

Figure 4 is an illustration similar to Figs. 2 and 3 of the distribution of paper web temperature in the machine direction of the dryer section.

Figure 5 illustrates the evaporation capacity of stage III in accordance with the invention as a function of the dry solids content percentage of the web in the method in accordance with the invention and in a prior-art dryer section.

Figure 1A shows a particularly favourable overall concept of a dryer section in accordance with the invention. As is shown in Fig. 1A, the paper web W is passed from the press section 10 of the paper machine at a dry solids content of $k_0 \approx 35...55$ % and at a temperature of $T_0 \approx 30...60°C$ on the bottom face of the transfer fabric 11 and supported by a *PressRun*™ box 11a onto the top face of the drying wire 12 over its guide roll 13. The first planar drying unit R_1 comprises a blow hood 15, under which the web W to be dried runs on the horizontal run of the wire 12, which is supported by the rolls 14. Said horizontal run of the wire 12 forms a plane consisting of grooved rolls and/or of suction boxes or blow boxes to support the web W. In the unit R_1, an intensive drying energy impulse is applied to the web W, in which connection, after the unit R_1, the temperature of the web W is $T_1 \approx 60...85°C$. In the unit R_1, primarily heating of the web W and of the water con-

tained in it takes place, but no substantial evaporation of water as yet. The length L_1 of the unit R_1 in the machine direction is typically of an order of $L_1 \approx 3...10$ m.

In the unit R_1, the paper web runs on support of the upper run of the drying wire 12 along a linear path in the horizontal plane so that it has no major changes in the direction and that, thus, no high dynamic forces are applied to it which might produce a web break in the web, which is still relatively moist and, thus, of low strength. In the interior of the blow hood 15, there is a nozzle arrangement, by whose means hot drying gases, such as air or steam, are blown against the top face of the web. Additionally or alternatively, it is possible to employ infrared heaters. Said blow devices and/or radiators in the unit R_1 can be arranged so that their output in the cross direction of the web W is adjustable so as to provide profiling of the web W in the cross direction.

In Fig. 1A, the unit R_1 is followed by the first so-called normal (not inverted) single-wire unit R_2, onto whose drying wire 22 the web W is transferred as a closed draw in the area of the first reversing suction roll 21. The single-wire unit R_2, and so also the subsequent single-wire units R_4, R_6 and R_8 that are open towards the bottom comprise steam-heated contact-drying cylinders 20 fitted in the upper row and reversing suction rolls 21 fitted in the lower row, for example the applicant's said *VAC-rolls*™. Below the cylinders 20, there are doctors and ventilation blow devices 25. The paper web W to be dried enters into direct contact with the faces of the steam-heated drying cylinders 20, and on the reversing suction rolls 21 the web W remains on the drying wire 22 at the side of the outside curve.

In Fig. 1A, after the group R_2 with single-wire draw, there follows a drying unit R_3 in accordance with the invention, which, in accordance with Fig. 1B, comprises two contact-drying cylinders 30 and a large-diameter D_1 impingement-drying/through-drying cylinder 31 with a perforated mantle, which cylinder will be called a large cylinder in the following. Around the contact-drying cylinders 30 and around the large cylinder 31, a drying wire 32 is fitted to run, which wire is guided by the guide rolls 33. The impingement-drying/through-drying hood module M_1 of the

drying unit R_3 is fitted in the basement space KT underneath the floor level K_1—K_1 of the paper machine hall on support of the floor level K_2—K_2 of said space. The central axes of the contact-drying cylinders 30 in the unit R_3 and in the corresponding following drying units R_5 and R_7 in accordance with the present invention are placed substantially in the floor plane of the paper machine hall or in the vicinity of said plane K_1—K_1, preferably slightly above said plane. The paper web W to be dried is passed from the single-wire unit R_2 as a closed draw onto the first drying cylinder 30 in the drying unit R_3 (R_n), after which the web W is passed on the wire 32 of the unit R_3 over the large cylinder 31 of the first module M_1 on a remarkably large sector b $\approx$ 220...280° on support of the drying wire 32 and further onto the second drying cylinder 30 in the unit R_3 (R_n). From this drying cylinder 30 the web W is transferred as a closed draw into the next normal unit R_4 with single-wire draw, which unit is substantially similar to the unit R_2 described above. After this, there follows the second drying unit R_5 (R_n), which unit is similar to the drying unit R_3 described above and whose large cylinder 31 is also placed in the basement space KT. After the drying unit R_5 the web W is passed as a closed draw into the next single-wire unit R_6, which is followed by the third drying unit R_7 (R_n), whose large cylinder 31 is likewise placed in the basement space KT. The unit R_7 is followed by a particular single-wire unit R_8, from which the web W_{out} is passed to the reel-up or into a finishing unit (not shown). The construction and operation of the particular unit R_8 will be described in more detail later with reference to Fig. 1C.

In the basement space, besides the modules M_1, M_2 and M_3, Fig. 1A also shows the pulpers 40a and 40b, between which there is the broke conveyor 41, which carries the paper broke into the pulper 40a and/or 40b. In the event of a web break, the web W can be passed after the unit R_1 directly into the pulper 40a placed underneath. The single-wire units R_4, R_6, and R_8 are open towards the bottom, and therefore the paper broke falls from them by the effect of gravity onto the broke conveyor 41 placed underneath or directly into the pulpers 40a,40b. Also the modules M_1, M_2 and M_3 are open or openable towards the bottom so that the paper broke falls out of connection with them, substantially by the effect of gravity, without major manual operations, onto the broke conveyor 41 placed underneath.

Underneath the modules M_1, M_2 and M_3, above the floor level K_2—K_2 of the basement space KT, there is still space KT_0 for various devices, such as ducts through which the heating medium, such as heated air or steam, is passed into the interior of the hoods 35 of the modules M_1, M_2 and M_3. Said lower space KT_0 is defined from below by the floor level K_2-K_2 of the basement space and from above by the partition wall 42 placed below the broke conveyor 41. On the drying units R_2...R_8 there is an air-conditioned hood 50 in itself known.

Figure 1B is a more detailed illustration of the impingement-drying/through-drying hood module M in accordance with the invention. As is shown in Fig. 1B, the wire 32a which runs around the large cylinder 31 is first passed around the last lower cylinder 21a in the preceding group R_{n-1} with single-wire draw onto the first contact-drying cylinder 30 in the unit R_n, from it further as a short straight run over the sector b $\approx$ 220 ... 280° of the large cylinder 31 onto the second contact-drying cylinder 30 in the group R_n and over said cylinder on a sector of about 90°. After this the web W follows the face of the cylinder 10 and is transferred as a closed draw onto the drying wire 22 of the next group R_{n+1}. The hood of the large cylinder 31, which consists of two parts 35, covers the cylinder substantially over the entire curve sector b of the wire 32a and the web W. On the sector b the web W remains on the wire 32a at the side of the outside curve, so that its outer face is free. The large cylinder 31 is mounted on its axle journals 36, through which a communication is arranged with vacuum devices (not shown), by whose intermediate a suitable vacuum is produced in the interior of the cylinder 31, which vacuum is of an order of $p_0 \approx 1...3$ kPa. This vacuum p_0 keeps the web W on the wire 32a when the web W is at the side of the outside curve, and, at the same time, the vacuum p_0 also promotes possible through-drying taking place through the web W and the wire 32a. The sector 360°-b that remains outside the sector b on the large cylinder 31 is covered by a cover plate 34 placed in the gap between the drying cylinders 30, and so also the last cylinder 21a in the group R_n, which can also be called the reversing cylinder of the group R_n, is covered by an obstacle plate 29. As to its more detailed embodiment, the perforated and grooved outer mantle 31a of the large cylinder 31 is, for example, similar to that described in said *FI Pat. Appl. 931263* and illustrated

above all in Fig. 11 of said patent application, so that the construction will not be described again in this connection.

In accordance with figure 1B, the large cylinder 31 is mounted by means of its axle journals 36 on support of the frame construction 37. In this frame construction, both at the driving side and at the tending side, there are horizontal and machine direction beams 37a, on whose top face, or on rails provided on said top face, the hood halves 35 are arranged to be movable on wheels 39, which hood halves are illustrated in the open position 35a, in which the module M can be serviced. The hood halves 35 are displaced into the open and closed positions by actuating cylinders 38. The module M and its hood 35 are open towards the bottom, so that broke can be removed in the direction of the arrows WA substantially by the effect of gravity onto the broke conveyor 41 placed underneath without substantial manual operations. The top face of the hood 35 has been shaped as smoothly downwards inclined so as to improve the removal of broke.

Further, in the open position 35a of the hood 35, the module M can also be serviced and cleaned easily in other respects. The diameter D_1 of the large cylinder 31 is, as a rule, chosen in the range of $D_1 > 2$ m, as a rule in the range of $D_1 \approx 2...8$ m, preferably $D_1 \approx 2...4$ m. The diameter D_2 of the drying cylinders 30 in the group R_n is, as a rule, chosen in the range of $D_2 \approx 1.5...2.5$ m, preferably in the range of $D_2 \approx 1.8...2.2$ m. In the groups R_{n-1} and R_{n+1} with single-wire draw, the diameter of the drying cylinders 20 is preferably $\approx D_2$. The diameter D_3 of the reversing suction cylinders 21,21a is, as a rule, chosen in the range of $D_3 \approx 0.6...1.8$ m, preferably $D_3 \approx 1.0...1.5$ m. The top face of the hood 35 has been shaped as smoothly downwards inclined to improve the removal of broke.

The wire 32a guide roll 33a placed above the latter drying cylinder 30 can be stationary or displaceable. Between the groups R_{n-1}, R_n and R_{n+1} a little difference in speed can be employed, which is, typically, about 0.1...0.2 %, so that, on the wires 22,32a,22, the speed becomes higher when the web W moves forwards. In the final end of the dryer section, the difference in speed can also be reversed.

The more detailed construction of the hood 35 of the module M and the circulation arrangements of the drying gases that are blown through it are described in detail in the *FI Patent Application No. (971713)* to be filed on the same day with the present application by the applicant, especially in its Fig. 3 and the related specification part, to which reference is made in this connection.

Fig. 1C shows, in a larger scale than Fig. 1A, the last group R_8 with single-wire draw in the dryer section in accordance with the invention, in which group the third stage of the invention is carried out. The paper web W to be dried is brought into the group R_8 from the last contact-drying cylinder 30 of the module M_3 shown in Fig. 1A as a closed draw onto the first reversing suction roll 61 of the group R_8. There are five of these reversing suction cylinders inside the wire loop 62 in the group R_8. The group R_8 includes five contact drying cylinders 60,60A. Two middle ones 60A of these cylinders are contact drying cylinders whose diameter, which is larger than that of the other cylinders 60, is $D_4 \approx 1.8...2.5$ m, whereas the diameter of the smaller cylinders 60 is $D_5 \approx 1.0...1.8$ m, and the diameter of the reversing suction cylinders 61 is $D_6 \approx 1.0...1.5$ m. Between the reversing suction cylinders 61 there are blowing devices 65 to ventilate the spaces between the cylinders 60,60A and 61 and to promote the drying. There is a blow box 64 above the upper sectors of the reversing suction cylinders 61 free from the web W and from the wire 62, which promotes maintenance of the vacuum inside cylinders 61.

In order that it should be possible to carry out the stage III of the method in accordance with the invention and to achieve a sufficiently high evaporation capacity and an increase in the web W temperature T_w in accordance with the curve T_I of Fig. 4 by means of the group R_8 shown in Fig. 1C, a drying effect is applied to the web W by means of contact drying cylinders 60A with large diameter also from the top face of the web W, i.e. from the drying wire 62. For this purpose ventilation hoods 66 are provided above the cylinders 60A, into which hoods sufficiently hot and dry drying air gases are passed through the intake pipe 67. Out of the pressurized interior of the ventilation hoods 66, the humidified ventilation air is discharged into the hood 50 around the dryer section, from where it is removed in a way known

from the prior art. These drying gases are blown against the drying wire 62 in the sector d of the cylinders 60A, said sector being preferably d $\approx$ 180° or even larger. Thus, evaporation of water is promoted through the upper face of the web W through the wire 62. The ventilation hoods 66 are shown in their open position 66a, as well as their air intake pipes are shown in their open position 67a. In this position 66a it is possible to clean and service the ventilation hoods, and the web W threading is also carried out most favourably then. In respect of their construction the ventilation hoods 66 can be similar to those that are described in more detail in the *FI Patent Application (971713)* to be filed on the same day with the present application.

In respect of the various details of the construction and the operation of the ventilation hoods 66, reference is made to the prior art coming out from the applicant's *FI Patent Application 951746* and from the *FI Patent 83,679 of Teollisuusmittaus Oy*.

Fig. 2 shows the development of the dry solids content KA of the paper over the length L of the dryer section in the machine direction as a function. The curve K represents an optimized method in accordance with the invention, and the curve K_{PA} represents the development of the dry solids content with a method and a dryer section of prior art. The curves K and K_{PA} have been obtained by means of computer simulation using the applicant's dryer section process model. The basis for the curve K_{PA} is the applicant's prior-art *SymRun*™ dryer section concept, which consists of N pcs. of successive groups with single-wire draw that are open towards the bottom, and the curve K is based on a dryer section concept in accordance with Fig. 1.

It can be noticed immediately from Fig. 2 that it has been possible to shorten the length of the dryer section from the length L_{PA} to the length L_I, i.e. in practice by about 15...40 percent. In accordance with Figs. 1...4 the method in accordance with the invention is divided into three different stages I, II and III. As is seen in Fig. 2, in the first stage I the rate of increase in dry solids content KA of the web W becomes higher from the initial value K_0 more steeply in accordance with the curve

K, in comparison with the curve K_{PA}, because the initial temperature of the web W is higher, which becomes clear from a comparison of the temperature curves T_I and T_{PA} of the stage I in the figure. Also, in the first stage I, as is shown in Fig. 3, the evaporation efficiency PE is, in accordance with the curve PE_I, substantially higher than in the prior-art method, curve PE_{PA} of stage I (Fig. 3). In the invention the first phase I is carried out on a horizontal dryer unit R_1 where the web W temperature T_W is raised to about 55...85°C, preferably to about 70°C, as comes out from Fig. 4. In the invention this raising of the temperature can be carried out very quickly, because in the unit R_1 a highly energy-intensive impingement stage and/or infra radiation can be used, because heating of the web W takes place free of contact so that there is no risk of sticking.

Stage II, shown in Figs. 1...4, is the main evaporation area where, in accordance with Fig. 2, the dry solids content KA of the web increases more steeply than in stage I as the drying proceeds. Fig. 3 shows the three successive evaporation peaks PE_1, PE_2 and PE_3 of stage II, at which the maximal evaporation efficiency PE is of an order of $PE \approx 60$ kg/m^2/h (kilograms per square meter in an hour). These evaporation peaks are achieved by the hood modules M1, M2 and M3 in the dryer section shown in Fig. 1. Depending on the mode of operation of the modules M1, M2 and M3 or equivalent, the maximal evaporation efficiency can be even higher. Between said peaks PE_1, PE_2 and PE_3, the evaporation efficiency PE is of an order 20 kg/m^2/h, i.e. of the same order of magnitude as the evaporation efficiency in accordance with the curve PE_{PA} in Fig. 3 on the average.

In the exemplifying embodyment of Fig. 4, the web temperature T_W stays substantially invariable in the stage II in accordance with the curves T_I and T_{PA} in a range of about 60...70°C. As was stated, the stage II is the main evaporation area where the water is evaporated from between the fibres in the web W and from the fibre surfaces.

In the third stage III in accordance with the invention, the steepness of the increase in the dry solids content decreases in comparison with stage II. The evaporation effi-

ciency also decreases in accordance with Fig. 3, whereas the web W temperature T_W starts rising from about 70°C to 100...110°C. In the corresponding location in the dryer section in the machine direction, in prior-art methods, the evaporation efficiency still remains invariable, in accordance with the curve PE_{PA} in Fig. 3, and so also the temperature in accordance with the curve T_{PA} in Fig. 4. In the dryer section in accordance with the invention, the stage III is carried out in the last cylinder group R_8, where the evaporation is made more intensive by means of the hoods 66 that are placed above the cylinders 60 A with large diameter, in which hoods sufficiently powerful and hot drying gases are applied to the web W placed under the drying wire 62 and to the environment of the wire 62, so that the web W temperature T_W can be raised very steeply in the stage III, in accordance with Fig. 4, in which connection also the water present inside the fibres in the paper web W can be efficiently evaporated on a sufficiently short length L of the dryer section in the machine direction. Fig. 5 illustrates the evaporation efficiency PE in the stage III of the invention, i.e. the dry solids content KA in the area KA 80...98 %. The curve PR_I represents the method in accordance with the invention, and the curve PE_{PA} a corresponding curve carried out by means of the prior-art *SymRun*™ concept. Fig. 5 shows that in the beginning of the stage III, in accordance with the curve PE_I, in the dry solids content area 80...82 the evaporation efficiency is substantially higher than in the prior-art concept and somewhat higher than in the dry solids content area 84...91 and in the dry solids content area 93...98. This improvement has mainly been carried out in the particular group R_8 by means of the drying cylinders 60A with large diameter and by means of the blowings from their ventilation hoods 66. Thus, in the drying method and in the dryer section in accordance with the invention, the ultimate dry solids content of the web W, $k_1 \approx 96...98$ %, is achieved in the machine direction length L_I of the dryer section, whereas in the prior art a substantially longer length L_{PA} was needed.

As comes out from the above and especially from Fig. 1A, the method stage I in accordance with the invention is carried out by applying drying energy mainly through the upper face of the web W. As is shown in Fig. 1, in the second stage II of the method, drying energy is applied to the web mainly through the lower face of

the web only by means of the wire groups R_3, R_4, R_5, R_6, R_7 and R_8 and by means of the hood modules M_1, M_2 and M_3, whereas in the group R_8 (Fig. 1C) and in the stage III drying energy is applied to the web W through its both faces by applying drying energy through the lower face of the web W by means of the contact drying cylinders 60 and 60A and through the upper face of the web by means of the ventilation hoods 66 on the sectors d of the cylinders. This arrangement provides a short dryer section in which, at the same time, it is possible to control the paper quality, for example its curl.

In this context it should be emphasized that the method in accordance with the invention can also be carried out with many other dryer section concepts and solutions of equipment besides those of Figs. 1A and 1B. Examples of these other dryer section concepts are some dryer section concepts described in the applicant's *FI Patent Applications Nos. (971713 and 971715)* to be filed on the same day with the present application. It is an essential feature of the dryer section in accordance with the invention that in said different drying stages I, II and III exactly a sort of a solution of equipment is used in which it is possible to carry out heating of the web and evaporation in accordance with the invention optimally. This inevitably has the consequence that, unlike the prior-art, in the different stages I, II and III of the invention, solutions of equipment different from one another have to be used, which is illustrated in Fig. 1.

In the following, the patent claims will be given, and the various details of the invention can show variation within the scope of the inventive idea defined in said claims and differ from the details described above by way of example only.

Claims

1. A method for evaporation drying of the paper web that comes from the press section (10) of a paper machine from a dry solids content of $k_0 \approx 35...55$ % to a dry solids content of $k_1 \approx 90...98$ %, **characterized** in that the method consists of three successive stages I, II and III that are carried out in the direction of progress of the web (W) in the sequence given as follows:

I in the first stage, the paper web coming from the press section (10) of the paper machine is heated in a short section (L_1) of the paper machine in the machine direction quickly to a temperature of 55...85°C, preferably to a temperature of about 70°C, and in this section (L_1) the web is passed so that web breaks of the relatively moist and, thus, weak web (W) are minimized,

II after the first stage (I), in this second stage (II) the main evaporation drying of the web (W) is carried out with such an evaporation efficiency (PE) and rate of increase in dry solids content (KA) per unit of length of the dryer section in the machine direction that said evaporation efficiency (PE) and rate of increase in dry solids content (KA) of the web (W) are substantially higher than in the first stage or in the final stage (III), and the web temperature (T_W) does substantially not rise in the second stage (II) while the drying proceeds (Fig. 4),

III in the third and final stage, the drying is continued with a decreasing evaporation efficiency (Fig. 3) and with such an average rate of increase in the dry solids content (KA) of the web (W) in the machine direction as is lower than in the preceding stage (II) but higher than in a conventional cylinder drying with single-wire draw so that the paper quality can be controlled at the same time.

2. A method as claimed in claim 1, **characterized** in that said first stage I is carried out by to the paper web (W), free of contact, applying an energy-intensive heating effect of a drying gas and/or of electromagnetic radiation, which will quickly increase the web (W) temperature.

3. A method as claimed in claim 1 or 2, **characterized** in that in said stage II, the main evaporation from between the fibres in the web (W) and from the fibre surfaces takes place so that evaporation efficiency peaks (PE_1, PE_2, PE_3) that are substantially higher than the basic evaporation efficiency (PE_0) are applied to the web (W).

4. A method as claimed in any of the claims 1 to 3, **characterized** in that in the last stage III of evaporation, in addition to contact drying, evaporation is carried out in a multi-cylinder dryer by, during the contact drying, outside the drying wire, to the web (W) applying drying gas flows that increase the evaporation substantially, in which connection also the water present in the fibres in the web (W) is evaporated.

5. A method as claimed in any of the claims 1 to 4, **characterized** in that in the second stage II evaporation power peaks are applied to the web (W), whose maximal evaporation efficiency (PE_1, PE_2, PE_3) is substantially higher, preferably about 2 to 4 times as high as the basic evaporation efficiency (PE_0) in this stage (II), and that said basic evaporation efficiency (PE_0) is dimensioned in the range of 10...30 $kg/m^2/h$, and that said maximal evaporation efficiencies (PE_1, PE_2, PE_3) are dimensioned in the range of 50...90 $kg/m^2/h$.

6. A method as claimed in any of the claims 1 to 5, **characterized** in that in the second stage (II) the dry solids content (KA) of the web (W) is increased from about 50% to about 80 %.

7. A method as claimed in any of the claims 1 to 6, **characterized** in that the evaporation efficiency peak or peaks (PE_1, PE_2, PE_3) in the second stage (II) are achieved by means of the impingement-drying/through-drying units (R_3, R_5, R_7)

between the contact drying cylinders (30), in which units energy-intensive drying gas jets are applied to the web (W) placed on the outer face of the drying wire (32) in the hood modules (M1, M2, M3), which are preferably placed in the basement space (KT) below the floor level (K_1—K_1) of the dryer section.

8. A method as claimed in any of the claims 1 to 7, **characterized** in that in stage III of the method the evaporation rate is increased in comparison with a normal cylinder drying with single-wire draw by increasing the relative proportion of the cylinder contact of the web (W).

9. A method as claimed in any of the claims 1 to 8, **characterized** in that in the third stage (III) drying is mainly carried out by means of one or several contact drying cylinders (60,60A) so that on one or several of said cylinders (60A), while the web (W) is pressed on the cylinders by the drying wire (62) against the heated face of the drying cylinder (60A), preferably a cylinder with a larger than average diameter (D_4), drying gas flows that promote the evaporation efficiency are applied to said drying wire (62) so that the water present inside the fibres in the web (W) is substantially evaporated (Fig. 1C).

10. A method as claimed in any of the claims 1 to 9, **characterized** in that the first stage (I) of the method is carried out by applying drying energy to the web (W) to be dried mainly through its upper face, that the second stage (II) of the method is carried out by applying drying energy to the web (W) to be dried through its lower face, and that the third stage (III) is carried out by applying drying energy to the web (W) to be dried through its both faces.

11. A dryer section of a paper machine for carrying out the method as claimed in any of the claims 1 to 10, **characterized** in that after the press section (10) of the paper machine, the dryer section comprises the following dryer units that are placed in the given sequence in the machine direction:

in order to carry out the first stage (I) of the method, the first unit (R_1) is a drying wire unit in which the paper web (W) runs past blow boxes and/or radiation dryer units, by whose means the web is heated without a direct contact with heated faces,

in order to carry out the second stage (II) of the method, dryer units (R_2...R_7) that comprise at least one single-wire group with single-wire draw that is open towards the bottom, in which the contact drying cylinders (20) are in the upper row and the reversing suction cylinders (21) are in the lower row so that removal of broke can take place downwards by the effect of gravity.

12. A dryer section as claimed in claim 11, **characterized** in that in order to carry out the last stage (III) of the method, the dryer section comprises one or several groups (R_8) with single-wire draw, a hood structure that increases the evaporation through the wire being mounted above one or several of the contact drying cylinders in said group.

13. A dryer section as claimed in claim 11 or 12, **characterized** in that, in order to carry out the last stage (III) of the method, the final end of the dryer section comprises one or several groups (R_8) with single-wire draw that is/are open towards the bottom and in which one or several contact drying cylinder(s), preferably contact drying cylinder(s) with a hood construction, is/are dimensioned so that its/their diameter is larger than the diameters of the other drying cylinders in said group (R_8) and/or of the drying cylinders (20) in the other groups with single-wire draw preceding the group concerned.

14. A dryer section as claimed in any of the claims 11 to 13, **characterized** in that the dryer section comprises two or three groups (R_2, R_4, R_6) with single-wire draw that are open towards the bottom, between and/or after which groups there is a dryer group or groups (R_3, R_5, R_7) provided with a drying wire (32), which groups comprise an impingement-drying/through-drying cylinder (31) with a large diameter (D_1) that is partially covered by a hood (35) and contact drying cylinders (30) at both sides above said impingement-drying/through-drying cylinder, to which

cylinders (30) the web (W) is brought from the preceding group (R_{n-1}) with single-wire draw and from the latter one of which cylinders (30) the web (W) is passed to the following group (R_{n+1}) with single-wire draw as a closed draw.

15. A dryer section as claimed in claim 14, **characterized** in that said impingement-drying/through-drying cylinders (31) are placed in the basement space (KT) below the floor level (K_1—K_1) of the paper machine hall while the groups (R_2, R_4, R_6, R_8) with single-wire draw are placed above said cylinders (31) above the floor level (K_1—K_1) of the paper machine.

16. A dryer section as claimed in claim 15, **characterized** in that said groups with single-wire draw and the hoods (35) of the impingement-drying/through-drying cylinders (31) permit removal of broke to take place towards the bottom by the force of gravity onto the broke conveyor (41) or equivalent placed underneath.

17. A dryer section as claimed in any of the claims 11 to 16, **characterized** in that, after the unit (R_1) that carries out the first stage (I), the dryer section comprises a unit (R_2) with single-wire draw and after that an impingement hood unit (R_3, M1), after that a unit (R_4) with single-wire draw, after that another impingement hood unit (R_5, M2), after that a third group (R_6) with single-wire draw, after that a third impingement hood unit (R_7, M3) and, in order to carry out stage III of the method, one or several single-wire groups (R_8) in which there are reversing suction cylinders (61) in the lower row, inside a drying wire loop (62), and contact drying cylinders (60, 60A) in the upper row, of which at least two cylinders (60A) have larger diameters (D_4) than the other cylinders and are provided with impingement hoods (66) (Fig. 1C).

AMENDED CLAIMS

[received by the International Bureau on 31 August 1998 (31.08.98); original claim 1 amended; remaining claims unchanged (5 pages)]

1. A method for evaporation drying of the paper web that comes from the press section (10) of a paper machine from a dry solids content of $k_0 \approx 35...55$ % to a dry solids content of $k_1 \approx 90...98$ %, **characterized** in that the method consists of three successive stages I, II and III that are carried out in the direction of progress of the web (W) in the sequence given as follows:

I in the first stage, the paper web coming from the press section (10) of the paper machine is heated in a short section (L_1) of the paper machine in the machine direction quickly to a temperature of 55...85°C, preferably to a temperature of about 70°C, and in this section (L_1) the web is passed while it is supported so that web breaks of the relatively moist and, thus, weak web (W) are minimized,

II after the first stage (I), the drying is continued as cylinder drying such that in this second stage (II) the main evaporation drying of the web (W) is carried out with such an evaporation efficiency (PE) and rate of increase in dry solids content (KA) per unit of length of the dryer section in the machine direction that said evaporation efficiency (PE) and rate of increase in dry solids content (KA) of the web (W) are substantially higher than in the first stage or in the final stage (III), and the web temperature (T_W) does substantially not rise in the second stage (II) while the drying proceeds (Fig. 4),

III in the third and final stage, the drying is continued as cylinder drying with single-wire draw with a decreasing evaporation efficiency (Fig. 3) and with such an average rate of increase in the dry solids content (KA) of the web (W) in the machine direction as is lower than in the preceding stage (II) but higher than in a conventional cylinder drying

with single-wire draw so that the paper quality can be controlled at the same time.

2. A method as claimed in claim 1, **characterized** in that said first stage I is carried out by to the paper web (W), free of contact, applying an energy-intensive heating effect of a drying gas and/or of electromagnetic radiation, which will quickly increase the web (W) temperature.

3. A method as claimed in claim 1 or 2, **characterized** in that in said stage II, the main evaporation from between the fibres in the web (W) and from the fibre surfaces takes place so that evaporation efficiency peaks (PE_1, PE_2, PE_3) that are substantially higher than the basic evaporation efficiency (PE_0) are applied to the web (W).

4. A method as claimed in any of the claims 1 to 3, **characterized** in that in the last stage III of evaporation, in addition to contact drying, evaporation is carried out in a multi-cylinder dryer by, during the contact drying, outside the drying wire, to the web (W) applying drying gas flows that increase the evaporation substantially, in which connection also the water present in the fibres in the web (W) is evaporated.

5. A method as claimed in any of the claims 1 to 4, **characterized** in that in the second stage II evaporation power peaks are applied to the web (W), whose maximal evaporation efficiency (PE_1, PE_2, PE_3) is substantially higher, preferably about 2 to 4 times as high as the basic evaporation efficiency (PE_0) in this stage (II), and that said basic evaporation efficiency (PE_0) is dimensioned in the range of 10...30 $kg/m^2/h$, and that said maximal evaporation efficiencies (PE_1, PE_2, PE_3) are dimensioned in the range of 50...90 $kg/m^2/h$.

6. A method as claimed in any of the claims 1 to 5, **characterized** in that in the second stage (II) the dry solids content (KA) of the web (W) is increased from about 50% to about 80 %.

7. A method as claimed in any of the claims 1 to 6, **characterized** in that the evaporation efficiency peak or peaks (PE_1, PE_2, PE_3) in the second stage (II) are achieved by means of the impingement-drying/through-drying units (R_3, R_5, R_7) between the contact drying cylinders (30), in which units energy-intensive drying gas jets are applied to the web (W) placed on the outer face of the drying wire (32) in the hood modules (M1, M2, M3), which are preferably placed in the basement space (KT) below the floor level (K_1—K_1) of the dryer section.

8. A method as claimed in any of the claims 1 to 7, **characterized** in that in stage III of the method the evaporation rate is increased in comparison with a normal cylinder drying with single-wire draw by increasing the relative proportion of the cylinder contact of the web (W).

9. A method as claimed in any of the claims 1 to 8, **characterized** in that in the third stage (III) drying is mainly carried out by means of one or several contact drying cylinders (60,60A) so that on one or several of said cylinders (60A), while the web (W) is pressed on the cylinders by the drying wire (62) against the heated face of the drying cylinder (60A), preferably a cylinder with a larger than average diameter (D_4), drying gas flows that promote the evaporation efficiency are applied to said drying wire (62) so that the water present inside the fibres in the web (W) is substantially evaporated (Fig. 1C).

10. A method as claimed in any of the claims 1 to 9, **characterized** in that the first stage (I) of the method is carried out by applying drying energy to the web (W) to be dried mainly through its upper face, that the second stage (II) of the method is carried out by applying drying energy to the web (W) to be dried through its lower face, and that the third stage (III) is carried out by applying drying energy to the web (W) to be dried through its both faces.

11. A dryer section of a paper machine for carrying out the method as claimed in any of the claims 1 to 10, **characterized** in that after the press section (10) of the paper

machine, the dryer section comprises the following dryer units that are placed in the given sequence in the machine direction:

in order to carry out the first stage (I) of the method, the first unit (R_1) is a drying wire unit in which the paper web (W) runs past blow boxes and/or radiation dryer units, by whose means the web is heated without a direct contact with heated faces,

in order to carry out the second stage (II) of the method, dryer units (R_2...R_7) that comprise at least one single-wire group with single-wire draw that is open towards the bottom, in which the contact drying cylinders (20) are in the upper row and the reversing suction cylinders (21) are in the lower row so that removal of broke can take place downwards by the effect of gravity.

12. A dryer section as claimed in claim 11, **characterized** in that in order to carry out the last stage (III) of the method, the dryer section comprises one or several groups (R_8) with single-wire draw, a hood structure that increases the evaporation through the wire being mounted above one or several of the contact drying cylinders in said group.

13. A dryer section as claimed in claim 11 or 12, **characterized** in that, in order to carry out the last stage (III) of the method, the final end of the dryer section comprises one or several groups (R_8) with single-wire draw that is/are open towards the bottom and in which one or several contact drying cylinder(s), preferably contact drying cylinder(s) with a hood construction, is/are dimensioned so that its/their diameter is larger than the diameters of the other drying cylinders in said group (R_8) and/or of the drying cylinders (20) in the other groups with single-wire draw preceding the group concerned.

14. A dryer section as claimed in any of the claims 11 to 13, **characterized** in that the dryer section comprises two or three groups (R_2, R_4, R_6) with single-wire draw that are open towards the bottom, between and/or after which groups there is a dryer

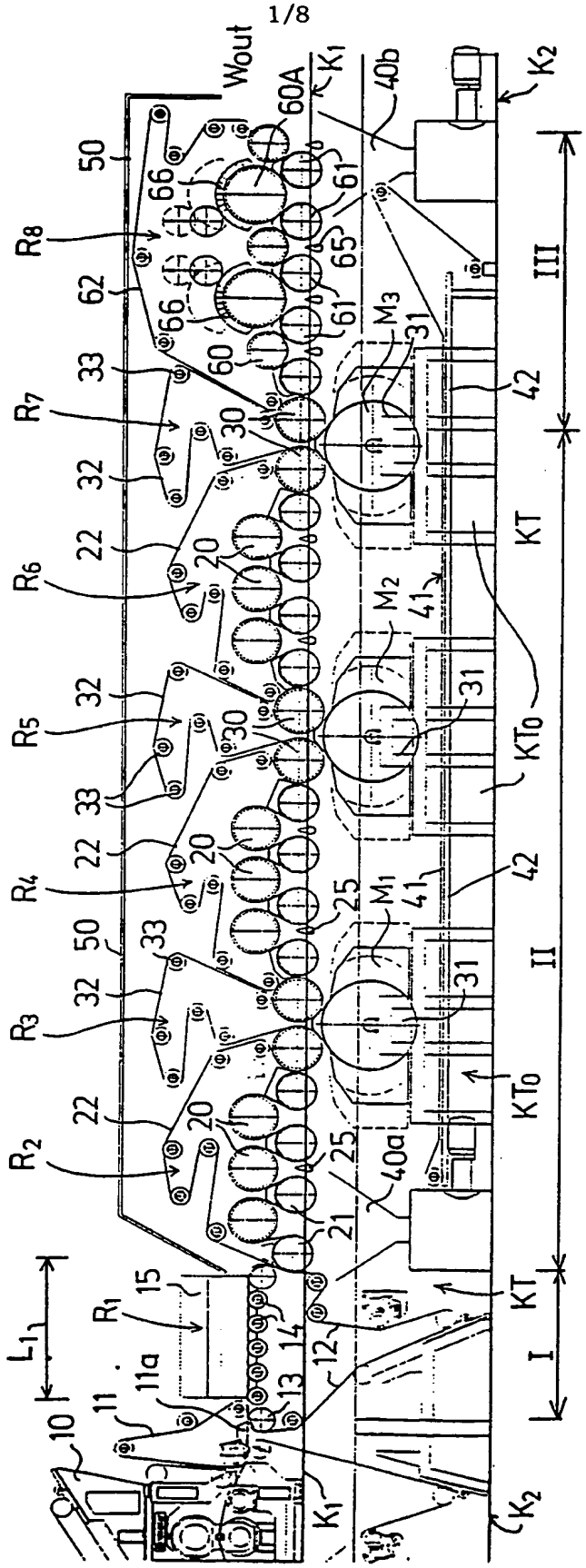
group or groups (R_3, R_5, R_7) provided with a drying wire (32), which groups comprise an impingement-drying/through-drying cylinder (31) with a large diameter (D_1) that is partially covered by a hood (35) and contact drying cylinders (30) at both sides above said impingement-drying/through-drying cylinder, to which cylinders (30) the web (W) is brought from the preceding group (R_{n-1}) with single-wire draw and from the latter one of which cylinders (30) the web (W) is passed to the following group (R_{n+1}) with single-wire draw as a closed draw.

15. A dryer section as claimed in claim 14, **characterized** in that said impingement-drying/through-drying cylinders (31) are placed in the basement space (KT) below the floor level (K_1—K_1) of the paper machine hall while the groups (R_2, R_4, R_6, R_8) with single-wire draw are placed above said cylinders (31) above the floor level (K_1—K_1) of the paper machine.

16. A dryer section as claimed in claim 15, **characterized** in that said groups with single-wire draw and the hoods (35) of the impingement-drying/through-drying cylinders (31) permit removal of broke to take place towards the bottom by the force of gravity onto the broke conveyor (41) or equivalent placed underneath.

17. A dryer section as claimed in any of the claims 11 to 16, **characterized** in that, after the unit (R_1) that carries out the first stage (I), the dryer section comprises a unit (R_2) with single-wire draw and after that an impingement hood unit (R_3, M1), after that a unit (R_4) with single-wire draw, after that another impingement hood unit (R_5, M2), after that a third group (R_6) with single-wire draw, after that a third impingement hood unit (R_7, M3) and, in order to carry out stage III of the method, one or several single-wire groups (R_8) in which there are reversing suction cylinders (61) in the lower row, inside a drying wire loop (62), and contact drying cylinders (60, 60A) in the upper row, of which at least two cylinders (60A) have larger diameters (D_4) than the other cylinders and are provided with impingement hoods (66) (Fig. 1C).

FIG. 1A


Wout
K1
K2
60A
40b
50
66
61
65
R8
62
M3
31
III
33
60
30
R7
42
32
KT
22
20
R6
M2
41
32
31
R5
30
KT0
33
22
20
R4
M1
41
25
42
50
33
II
32
31
R3
KT0
22
20
R2
25
40a
21
15
R1
KT
14
12
L1
11a
13
11
I
10
K1
K2

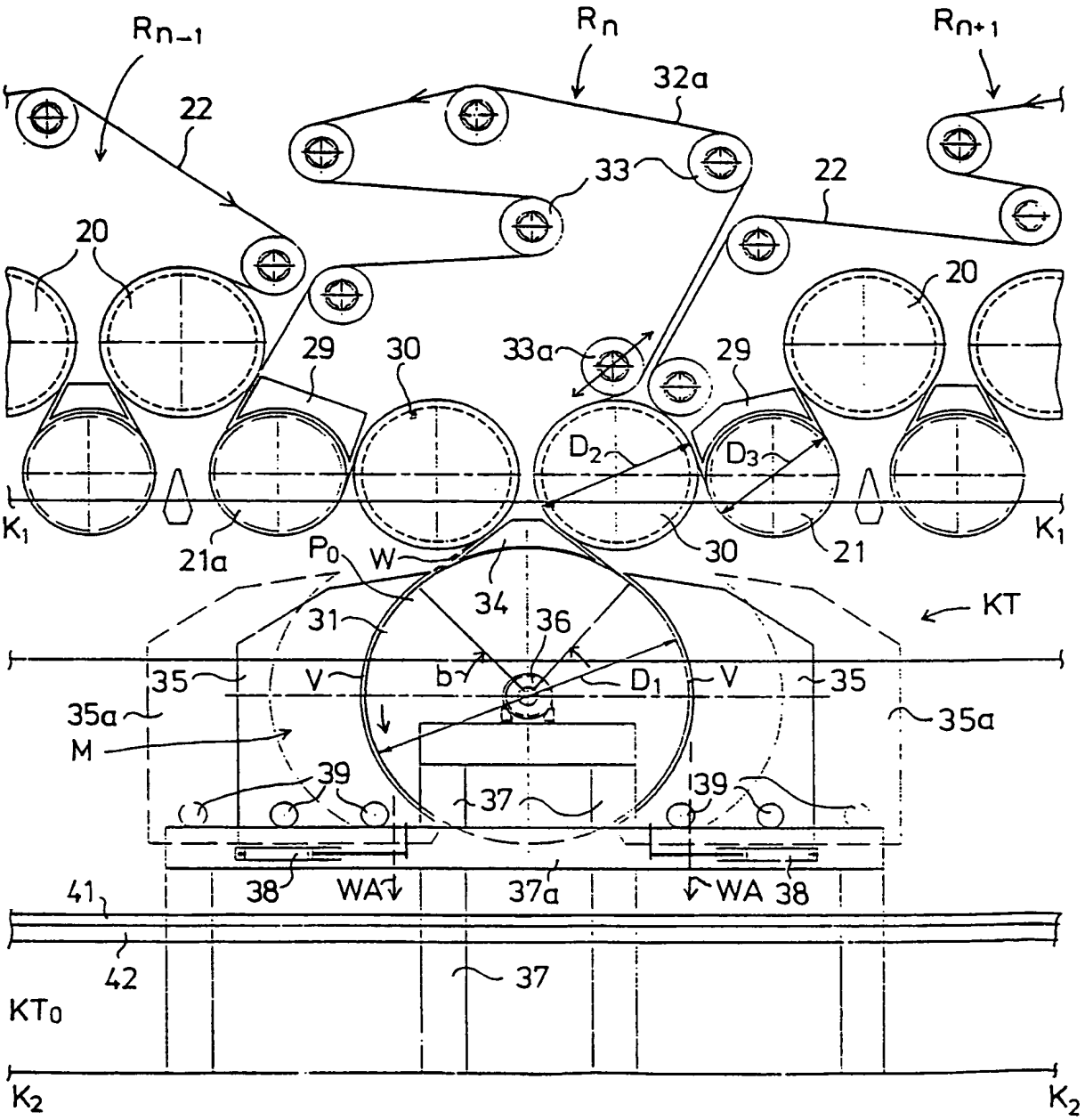

Rn-1
Rn
Rn+1
22
32a
33
22
20
20
29
30
33a
29
D2
D3
K1
K1
21a
P0
W
30
21
34
KT
31
36
35
V
b
D1
V
35
35a
35a
M
39
37
39
41
38
WA
37a
WA
38
42
37
KT0
K2
K2

FIG.1B

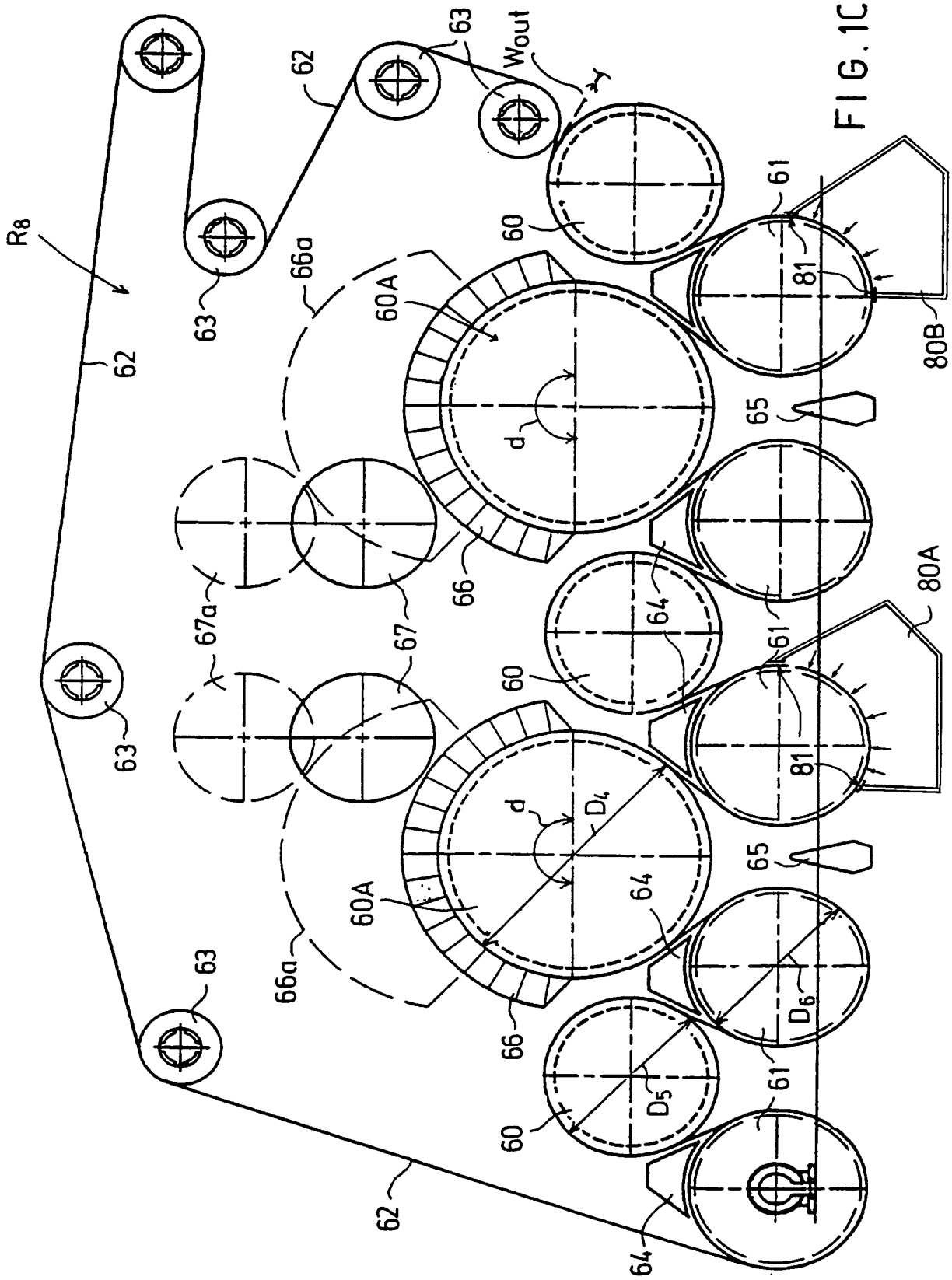


FIG. 1C

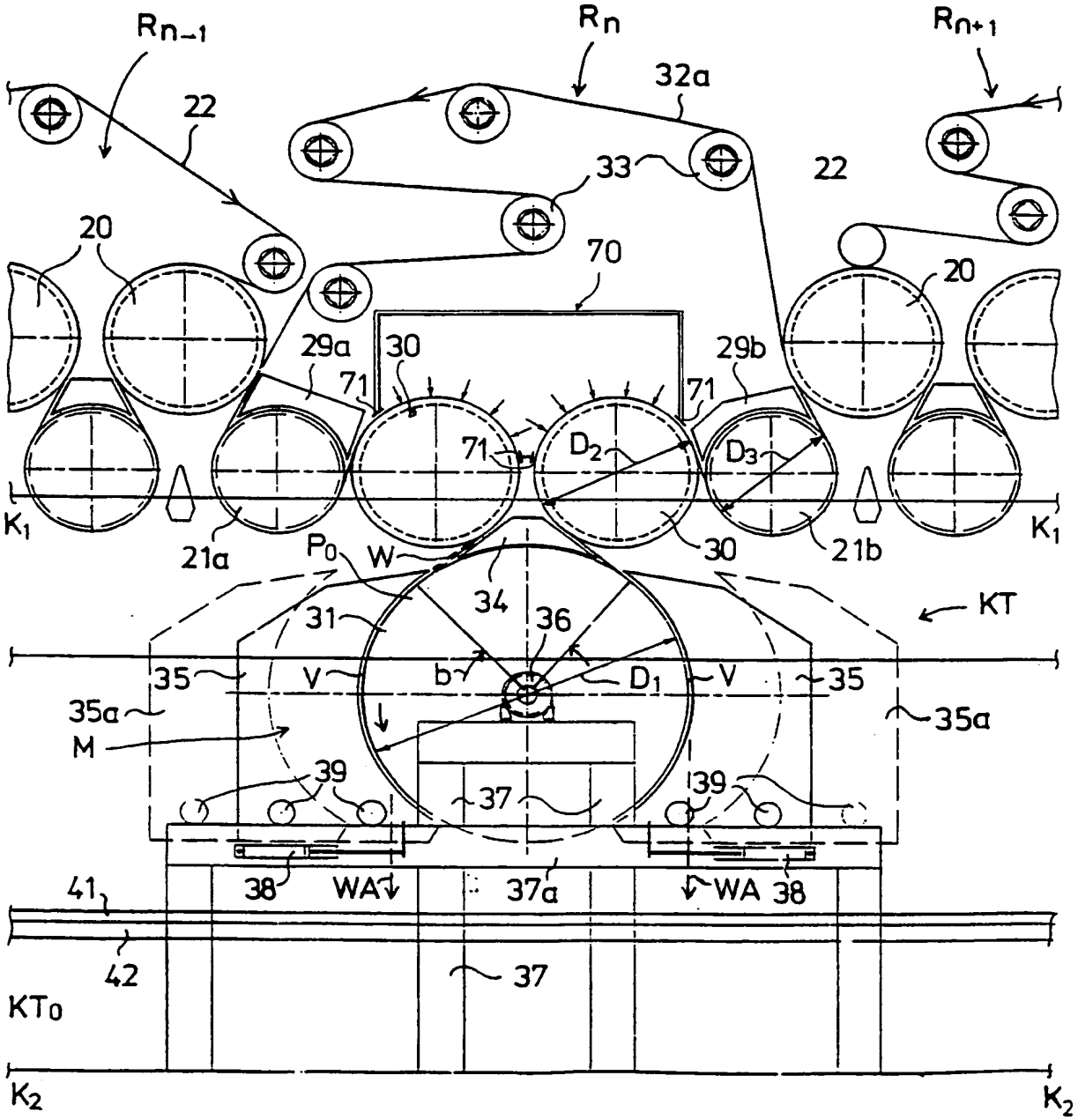

Rn-1
Rn
Rn+1
22
32a
33
22
20
70
20
29a
30
29b
71
71
71
D2
D3
K1
K1
21a
P0
W
30
21b
34
KT
31
36
35
V
b
D1
V
35
35a
35a
M
39
37
39
41
38
WA
37a
WA
38
42
37
KT0
K2
K2

FIG.1D

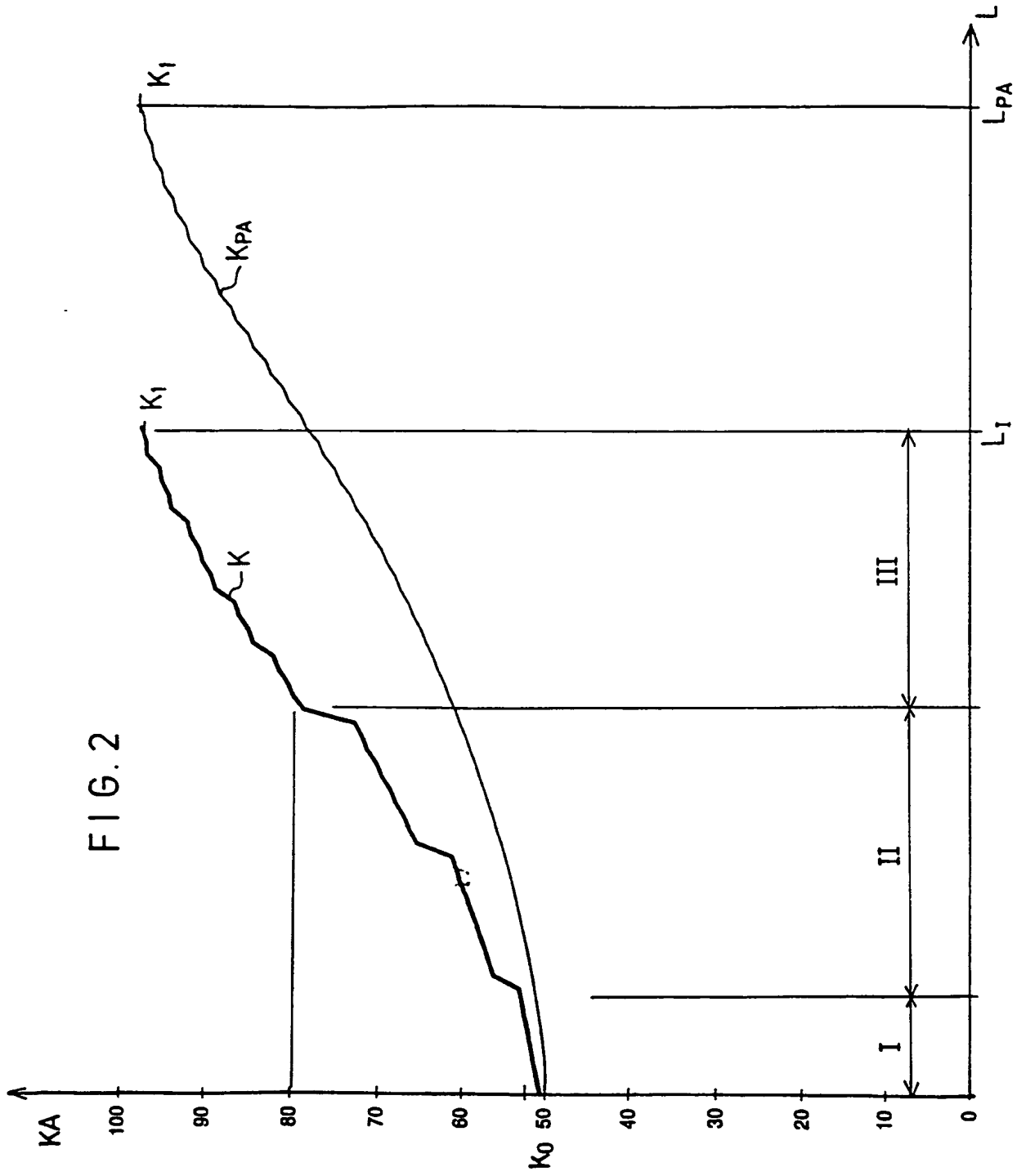
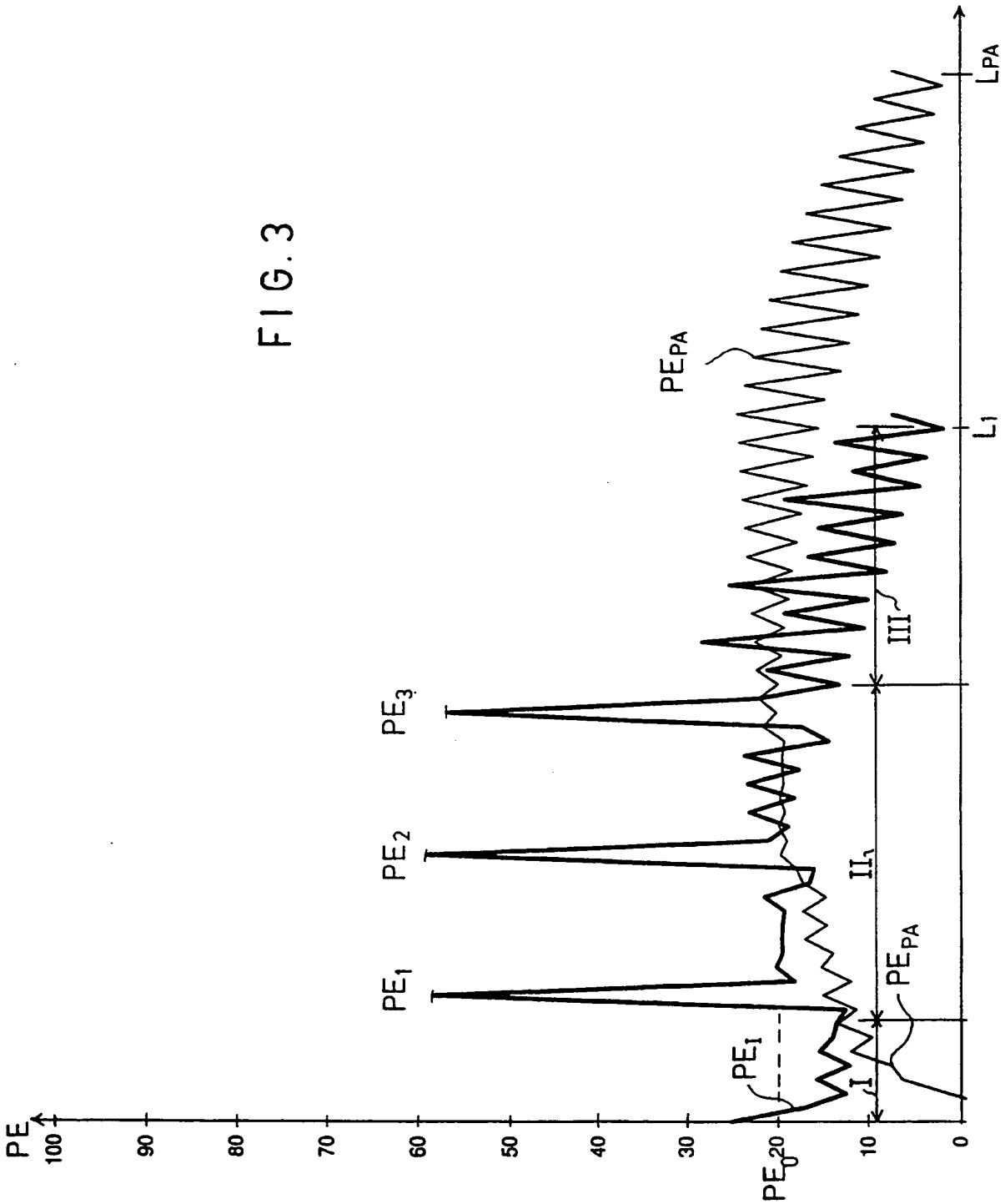


FIG. 2

FIG. 3


PE
100
90
80
70
60
50
40
30
20
10
0
PE0
PE1
PE2
PE3
PEPA
PE1
PEPA
I
II1
III
L1
LPA

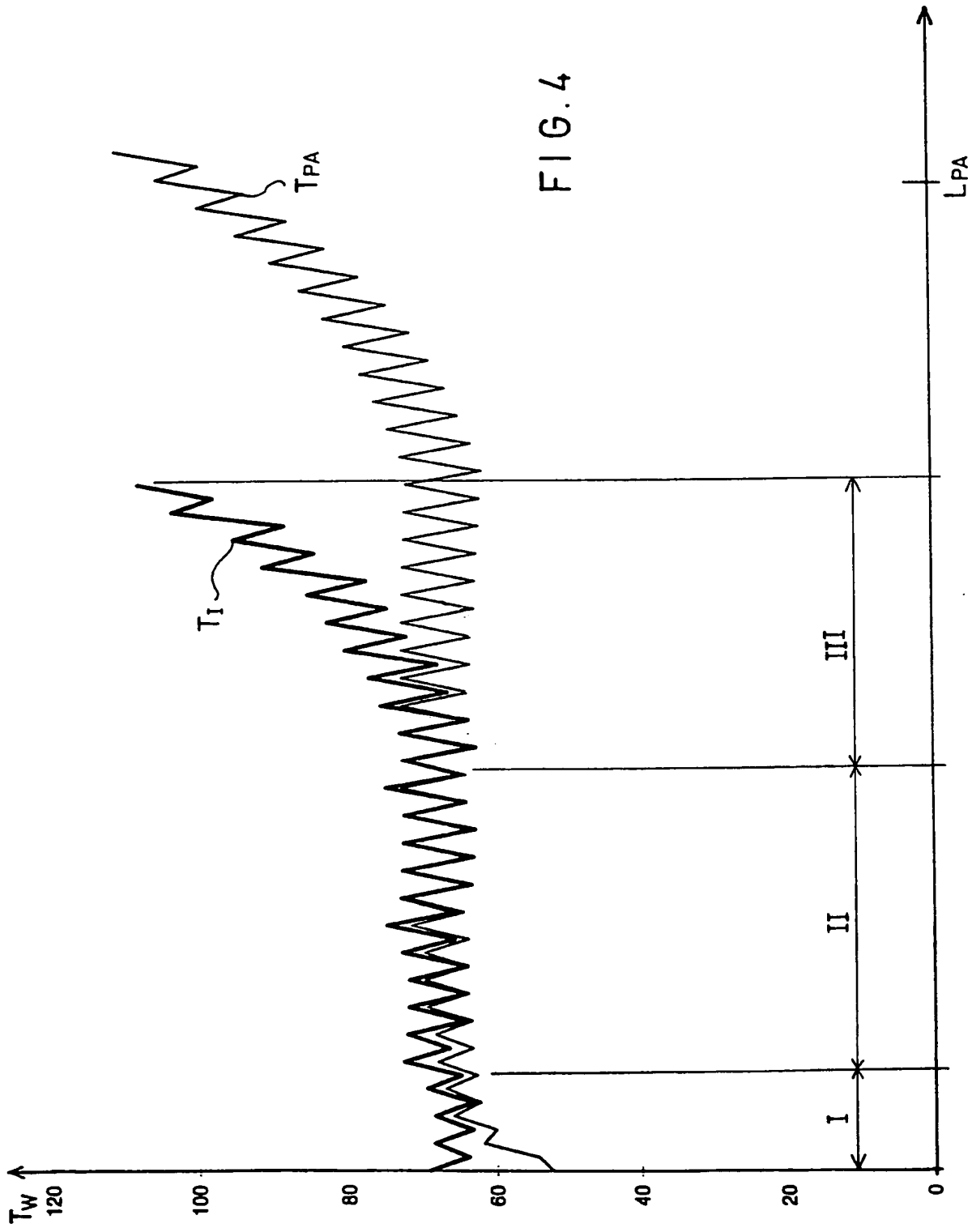
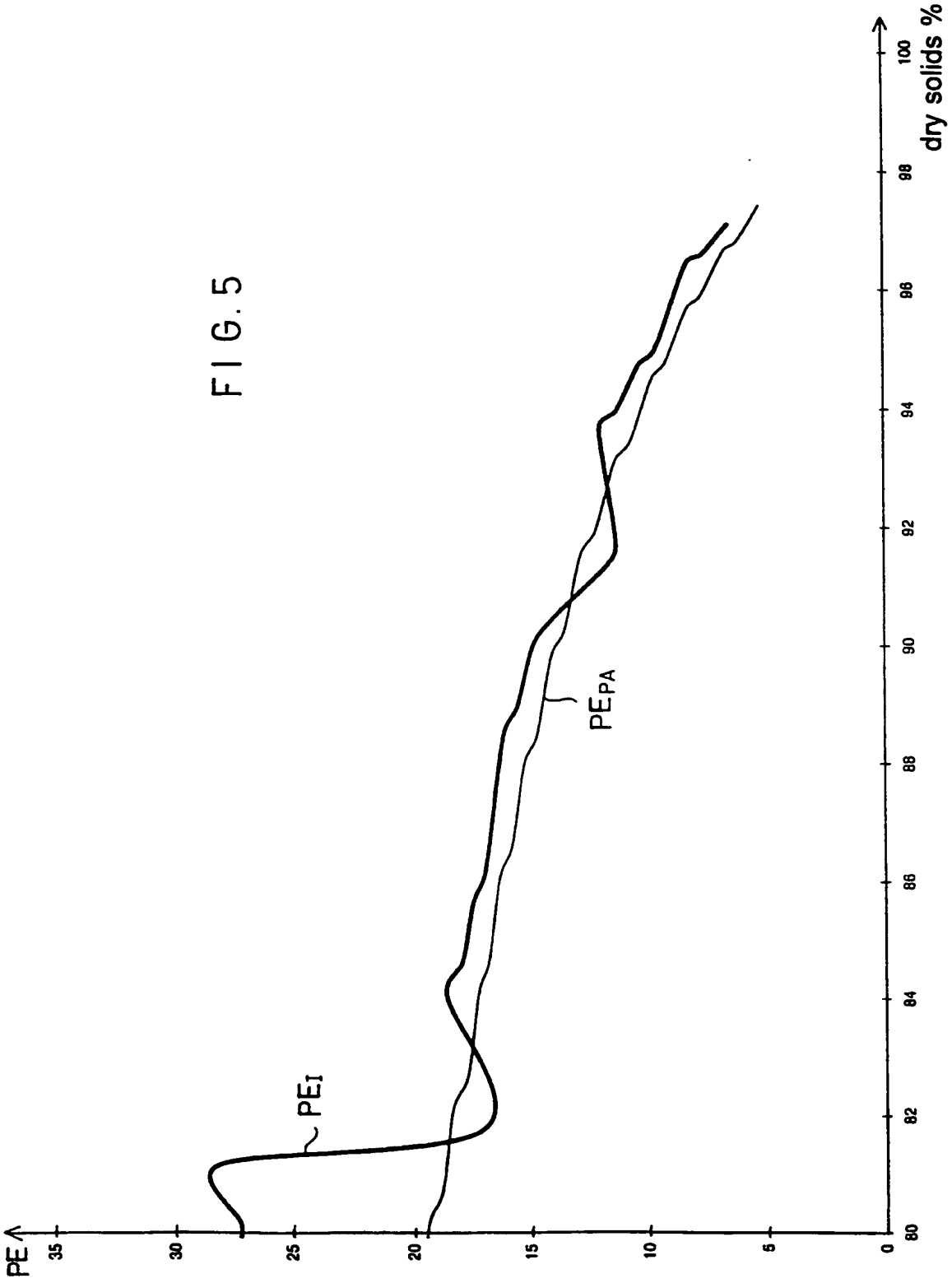


FIG. 4

FIG. 5


PE
35
30
25
20
15
10
5
0
80
82
84
86
88
90
92
94
96
98
100
dry solids %
PEI
PEPA

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 98/00351

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: D21F 5/04
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: D21F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4882855 A (LOSER ET AL), 28 November 1989 (28.11.89), column 6, line 19 - line 34, figure 4, abstract --	1-17
A	WO 8904890 A1 (VALMET OY), 1 June 1989 (01.06.89), page 14, line 12 - page 15, line 19, figures 1,2, 4B, abstract --	1-17
A	WO 9713031 A1 (VALMET CORPORATION), 10 April 1997 (10.04.97), page 17, line 18 - line 24, figure 11, abstract -- --------	1-17

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 June 1998	29 -06- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Björn Salén Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

09/06/98

International application No.
PCT/FI 98/00351

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